TECHBRIEF

The Federal Highway Administration—in collaboration with the Transportation Research Board, the National Cooperative Highway Research Program, State departments of transportation, and other Federal agencies—has been investigating the effects of highway transportation on air quality. These investigations have primarily dealt with the evaluation of air-contaminant emissions produced by motor vehicles at various speeds and under various highway conditions. Dispersion of air-contaminant emissions in various areas has been analyzed.

Highway agencies are also mandated to evaluate whether mobile-source emissions conform to State implementation plans and to make adjustments, as required, to meet ambient air quality standards.

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Issues Affecting Dispersion Near Highways: Light Winds, Intra-Urban Dispersion, Vehicle Wakes, and the Roadway-2 Dispersion Model

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The research described in the report, *Issues Affecting Dispersion Near Highways: Light Winds, Intra-Urban Dispersion, Vehicle Wakes, and the Roadway-2 Dispersion Model*, deals with the occurrence and peculiarities of calm winds; the influence of geometric features of urban topography as they influence ambient wind speed and fluctuations of airflow directions, both vertically and horizontally, in contrast to nearby rural locations; and the mixing of air behind moving vehicles and the subsequent dispersion of air contaminants, especially under low wind speed conditions. This study was a collaboration between the National Oceanic and Atmospheric Administration's (NOAA) Atmospheric Turbulence and Diffusion Division and the Federal Highway Administration (FHWA). Highway agencies must perform assessments of the likely impacts of traffic-related air pollutants near highways. Urban highways are a particular concern, and introduce a range of complications, particularly uncertainties about the wind and turbulence information needed to drive the air quality models.

This research covered several tasks. The first was a thorough study of light wind data, stratified by wind speed category and time of day, using observations from a number of research-grade meteorological networks in different locations around the United States. The instruments in these networks could resolve winds down to about 0.5 m/s, much lower than the threshold of most routine meteorological stations. Data from the humid and vegetation-covered southeastern United States, the arid northwest, and a coastal environment were those considered in the greatest detail. The results are covered in considerable detail, with explanations related to the physical mechanisms affecting the observations at the various sites. As an example case, the distribution of wind speeds was given for the Knoxville, TN airport, where light winds are common. Examples of findings include: (1) periods with winds less than 0.5 m/s seldom exceeded a few hours duration, (2) fully 35 percent of the 1-h periods revealed winds of 2 m/s or less, and (3) about 8 percent of the data showed 2-h periods of less than 0.5 m/s. Noteworthy observations were that wind roses, calculated for mean wind speeds somewhat below the common anemometer threshold wind speed of 1.5 to 2 m/s, were generally similar to those for slightly stronger winds (1.5 to 3.5 m/s), and comparisons of vector and mean absolute wind speeds indicated large variations in the horizontal wind directions. That is, there are larger variations in wind direction at lower wind speeds. This is an expected result.

Winds and turbulence within urban regions are of considerable interest, but relatively few measurements are available. Therefore, data were collected using three-dimensional sonic anemometers in Knoxville and Nashville, TN, as well as at nearby rural sites. The mean and turbulence quantities and spectra were compared to examine the ability to use data from airports or other rural observation locations in lieu of intra-urban data. The results indicate that on-site data are needed because city winds are significantly lower and turbulence levels are significantly higher within the cities than in the surrounding areas. Apparently, in the urban central city, the mean wind speed is reduced compared to nearby rural locations, but both the horizontal and vertical wind turbulence are increased due to the presence of buildings (hence, the dispersion coefficients σ_y and σ_z for air contaminant emissions are considerably greater for urban centers with large buildings).

There are few data available on the wakes of vehicles, which are known to affect the initial dispersion of vehicular effluents, especially under light wind conditions. Most available data are from wind tunnels. To provide real-world data, a special towable apparatus was constructed which supported six three-dimensional sonic anemometers for simultaneous measurements at different locations within the wake of the towing vehicle. Operations were carried out on an airport runway, away from the influence of buildings or other vehicles. Turbulent kinetic energy (TKE) was calculated at a number of locations in the near wake and the contours of the TKE were plotted. Flow vectors for various cross-sections of the wake were determined. The turbulent energy measurements indicated the influence of the vehicle movements on the mixing and movement of the air behind the towing vehicle and could indicate the region of initial mixing of vehicle exhaust.

It was also noted that the effects of moving vehicles can be detected by air turbulence measurements alongside the road and that passing vehicles could be detected not only by an enhanced horizontal momentum flux, but also by characteristic signatures of water vapor and carbon dioxide from their exhausts.

A new near-highway dispersion model, called ROADWAY-2, was developed. The model is based on the U.S. Environmental Protection Agency's (EPA) ROADWAY model, but it uses a TKE closure formulation for a time-varying atmospheric boundary layer to provide the mean wind and temperature profiles from input meteorological data. It allows the use of on-site turbulence data, which is increasingly feasible given recent instrumentation advances and lower costs. The parameterization of vehicle wake effects is also new, based on canopy flow theory and wind tunnel measurements. Comparisons of predicted and observed concentrations from the General Motors field study are generally good. More than 80 percent of the model predictions were within a factor of two of these data, and 95 percent were within a factor of five.

(Note: Extensive field data from meteorological, traffic flow, and vehicle exhaust air pollutant measurements were recently collected by another NCHRP 25-6 FHWA contractor for a separate project at highway intersections in Tucson, AZ; Denver, CO; and Loudon County, VA. The ROADWAY-2 model predictions were compared to the observations made in this large highway intersection air quality study.)

In addition to the work done here to provide highway agencies with a better understanding of both vehicle-induced and ambient air movements (winds) on air pollutant dispersion and the need for appropriate wind measurements, there are numerous other reasons for concern about micrometeorology and local wind flows, especially in urban areas and in areas of complex topography. These include concerns about mean winds and turbulence affecting aircraft, surface vehicles, highway structures, the dispersion of deliberate and accidental releases of toxic or hazardous vapors and gases, the spread of fires, etc. These problems are receiving increased attention from the U.S. Department of Energy, the U.S. Department of Defense, the Federal Emergency Management Agency, the National Aeronautics and Space Administration, and others, as well as components of various departments of transportation.

This study represents part of a limited participation by FHWA in more basic research under the Intermodal Surface Transportation Efficiency Act (ISTEA). In this case, micrometeorology or airflows related to traffic and dispersion of exhaust emissions were investigated.

Suggestions for future research are provided in the report.

Research—This research study was performed by the National Oceanic and Atmospheric Administration's Air Resources Laboratory, Atmospheric Turbulence and Diffusion Division. The principal investigator was Dr. Rayford P. Hosker, Jr., director of the Atmospheric Turbulence and Diffusion Division, 456 South Illinois Avenue, P.O. Box 2456, Oak Ridge, TN 37830, (865) 576-1233.

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Availability—The report on this study is available on the TFHRC website in the Research Library (go to *www.tfhrc.gov* and click on "Library"). Copies will be available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

Key Words—Low-speed winds, vertical and horizontal fluctuations of winds, intra-urban dispersion, turbulence kinetic energy, vehicle wakes, Roadway-2 Model, Dispersion under low wind conditions.

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